



# Fan Control and Integrated Economizers

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California Statewide Utility Codes and Standards Program

Taylor Engineering

April 27, 2011

## NR10 – Single Zone VAV

# Current Code Requirements

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- Title 24-2008:

- Effective 1/1/2012, DX and chilled water (CHW) units  $\geq 10$  tons shall be VAV
  - (have VFD or 2 speed supply fans to reduce speed below 2/3 of full speed at low load)

- ASHRAE 90.1-2010:

- Effective 1/1/2010, CHW units  $\geq 5$  hp shall be VAV
- Effective 1/1/2012, DX units  $\geq 10$  tons shall be VAV

## NR10 – Single Zone VAV

# Typical Practice

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### ● Fan Control:

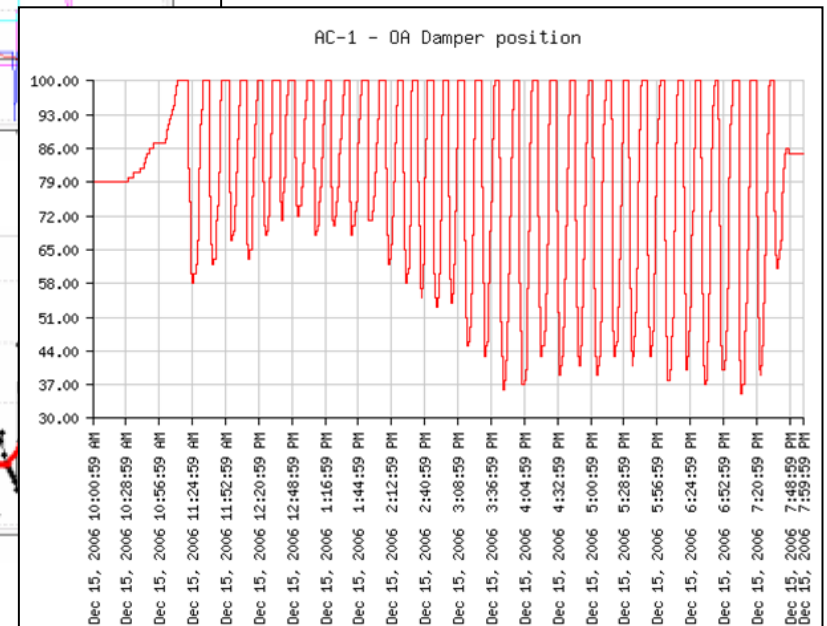
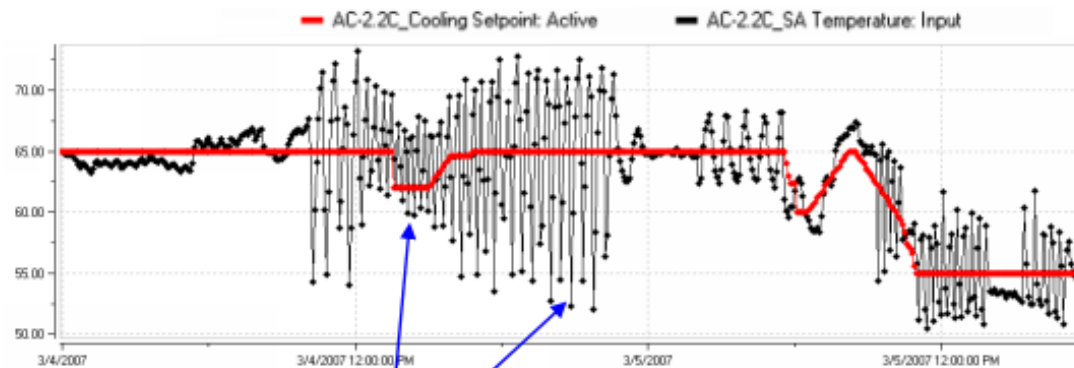
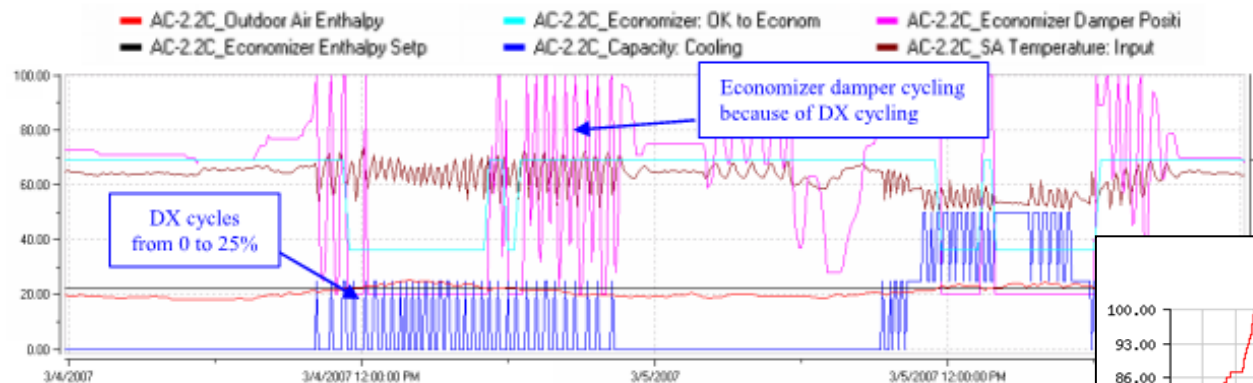
- Typical practice for single zone (SZ) units (CHW and DX) is constant volume
- We estimate less than 5% of SZ DX units are VAV
- We estimate less than 10% of SZ CHW units are VAV

## NR10 – Single Zone VAV

# Typical Practice

- Integrated Economizers:
  - Packaged units do not fully capture economizer savings because minimum compressor runtimes cause the economizers dampers to cycle

Figure 2 – AC Unit Control – M5 AC-2.2C



## NR10 – Single Zone VAV

### *SECTION 101 – DEFINITIONS AND RULES OF CONSTRUCTION*

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- **Multiple Zone System:** an air distribution system that supplies air to more than one thermal zone each of which has one or more devices (such as dampers, cooling coils, and heating coils) that regulate airflow, cooling, or heating capacity to the zone.
- **Single Zone System:** an air distribution system that supplies air to one thermal zone

## NR10 – Single Zone VAV

### SECTION 144 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

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#### 144 (c) Power Consumption of Fans. ...

1. Single zone systems and constant volume fan systems. The total fan power index at design conditions of each fan system with total horsepower over 25 hp shall not exceed 0.8 watts per cfm of supply air.
2. Multiple zone variable air volume (VAV) systems.
  - A. The total fan power index at design conditions of each fan system with total horsepower over 25 hp shall not exceed 1.25 watts per cfm of supply air; and
  - ~~B. Individual VAV fans with motors 10 horsepower or larger shall meet one of the following:~~
    - ~~i. The fan motor shall be driven by a mechanical or electrical variable speed drive.~~
    - ~~ii. The fan shall be a vane-axial fan with variable pitch blades.~~
    - ~~iii. For prescriptive compliance, the fan motor shall include controls that limit the fan motor demand to no more than 30 percent of the total design wattage at 50 percent of design air volume when static pressure set point equals 1/3 of the total design static pressure, based on certified manufacturer's test data.~~
  - B. Static Pressure Sensor Location. ...
  - C. Set Point Reset. ...

## NR10 – Single Zone VAV

### **SECTION 144 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS**

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#### **144 (e) Economizers.**

2. If an economizer is required by Subparagraph 1, it shall be:

B. Capable of providing partial cooling even when additional mechanical cooling is required to meet the remainder of the cooling load. Effective January 1, 2015, mechanical cooling shall be capable of staging or modulating capacity in increments of no more than 20% of total cooling capacity. Controls shall not false load the mechanical cooling system by limiting or disabling the economizer or any other means, such as hot gas bypass, except at the lowest stage of cooling capacity.

## NR10 – Single Zone VAV

### SECTION 144 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

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- ~~144 (I) Variable air volume control for single zone systems.~~ Effective January 1, 2012 all unitary air conditioning equipment and air handling units with mechanical cooling capacity at ARI conditions greater than or equal to 110,000 Btu/hr that serve single zones shall be designed for variable supply air volume with their supply fans controlled by two-speed motors, variable speed drives, or equipment that has been demonstrated to the Executive Director to use no more energy. The supply fan controls shall modulate down to a minimum of 2/3 of the full fan speed or lower at low cooling demand.
- 144 (I) Fan Control. Each *multiple zone system* and *single zone system* listed in Table 144-D shall be designed to vary the airflow rate as a function of actual load. *Single zone systems* shall have controls and/or devices (such as two-speed or variable speed control) that will result in fan motor demand of no more than 50 percent of design wattage at 66 percent of design fan speed. *Multiple zone systems* shall include controls that limit the fan motor demand to no more than 30 percent of the total design wattage at 50 percent of design air volume when static pressure set point equals 1/3 of the total design static pressure.



## NR10 – Single Zone VAV

### SECTION 144 – PRESCRIPTIVE REQUIREMENTS FOR SPACE CONDITIONING SYSTEMS

**144 (I) Fan Control.** Each *multiple zone system* and *single zone system* listed in Table 144-D shall be designed to vary the airflow rate as a function of actual load. *Single zone systems* shall have controls and/or devices (such as two-speed or variable speed control) that will result in fan motor demand of no more than 50 percent of design wattage at 66 percent of design fan speed. *Multiple zone systems* shall include controls that limit the fan motor demand to no more than 30 percent of the total design wattage at 50 percent of design air volume when static pressure set point equals 1/3 of the total design static pressure.

Table 144-D – Effective Date for Variable Airflow Control of Fan Systems

Cooling System Type	Fan Motor Size	Cooling Capacity <sup>a</sup>	Effective Date
<u>Direct Expansion</u>	<u>any</u>	<u>&gt; 110,000 Btu/hr</u>	<u>January 1, 2012</u>
<u>Direct Expansion</u>	<u>any</u>	<u>&gt;65,000 Btu/hr and &lt;110,000 Btu/hr</u>	<u>January 1, 2015</u>
<u>Chilled water</u>	<u>&gt;1/4 hp</u>	<u>any</u>	<u>January 1, 2012</u>
<u>Evaporative</u>	<u>&gt;1/4 hp</u>	<u>any</u>	<u>January 1, 2012</u>

<sup>a</sup>See Tables 112-A and 112-B for rating standard and conditions

**EXCEPTION 1 to Section 144(I):** Systems that supply 100% outdoor air and are required to be constant volume in order to maintain minimum ventilation or makeup air rates.

## NR10 – Single Zone VAV

# Analysis 1: Fan Control SZ DX

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- Cost data from AHRI member survey in January 2011: \$500 total incremental first cost for 6 ton unit to go from single speed/single stage compressor to two speed/two stage compressor
- Maintenance cost from Bay Area service contractors
- Energy analysis is conservative because:
  - We modeled 2 speed fan with 30% power at low speed. Most existing SZ VAV units have variable speed fans and go well below 30% power at low speed.
  - The analysis does not account for the significant reduction in energy losses associated with on-off cycling of single stage compressors compared to two stage compressors.
  - Does not account for oversizing
- Highly cost effective: less than 2 year simple payback

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# Analysis 2: Fan Control - CHW Fan Coil

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- Typical fan coil space - e.g. electrical room, computer closet
  - 24/7
  - No outside air
  - 60% average load
- Cost data from Bay Area equipment suppliers for ECM motor versus standard motor
- Highly cost effective at ¼ HP

## NR10 – Single Zone VAV

# Analysis 3: Fan Control - CHW AHU

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- Simulation of typical office space
- Includes incremental cost to add a modulating actuator to minimum outside air damper to maintain minimum outside air as fan modulates
- Cost data from
  - Bay Area equipment suppliers for ECM motor versus standard motor or VFD
  - Damper actuator supplier
- Analysis is conservative because
  - It does not take credit for reduced fan heat cooling energy.
  - It does not take credit for the increased motor efficiency of an ECM versus a standard PSC motor.
- Cost effective for AHU serving 500 ft<sup>2</sup>

## NR10 – Single Zone VAV

### Analysis 4: Integrated Economizer Multiple Zone DX

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- Simulation of typical office space
  - Basecase: 75% economizer savings
  - Proposed case: 100% economizer savings
- Cost data from AHRI member survey in January 2011: \$700 total incremental first cost for 6 ton unit to go from two stage compressor to variable capacity compressor (e.g. Copeland Digital Scroll)
- This analysis is conservative because it only takes credit for economizer savings and does not take credit for compressor efficiency savings (e.g. reduced cycling, more effective use of heat exchangers)
- Highly cost effective even at 6 tons (most multiple zone units are at least 15 tons)

## NR10 – Single Zone VAV

# Analysis 5: Fan Control and Integrated Economizer – Single Zone DX

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- Simulation of typical office space
  - Basecase: constant speed fan, partially integrated economizer
  - Proposed case: variable speed fan, fully integrated economizer
- Cost data from AHRI member survey in January 2011: The incremental cost for a variable capacity compressor and a variable fan over a single stage compressor and a single speed fan is \$2,133 for a 6 ton unit.
- Incremental maintenance assumed to be 1 hour but is probably negative due to reduced wear and tear on compressors and dampers due to reduced cycling.
- This analysis is conservative because it only takes credit for fan and economizer savings and does not take credit for compressor efficiency savings (e.g. reduced cycling, more effective use of heat exchangers)
- Highly cost effective even at 6 tons – simple payback around 2 years

## NR10 – Single Zone VAV

# Measure Availability

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- Two speed or variable speed fans on 6 ton or smaller DX units
  - Aeon
  - Carrier
  - Daikin
  - Mitsubishi
  - JCI/York
  - Mammoth
- Multiple stage or variable capacity compressors on 6 ton or smaller DX units
  - Aeon – digital scroll
  - Carrier – digital scroll
  - Daikin – variable speed compressor
  - Mitsubishi – variable speed compressor
  - JCI/York – variable speed compressor expected by 2012
- Variable speed models of reciprocating, scroll and rotary compressors are all commercially available. They have been in widespread use for many years in Asia and are now increasingly used in the U.S.

## NR10 – Single Zone VAV

# Non-Energy Benefits

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- Improved air quality
    - A truly integrated economizer is able to keep the economizer enabled in economizer mode and provide more fresh air
    - Systems without proper integration end up excessively cycling the economizer dampers. This often causes the dampers to fail prematurely. Typically they fail in the closed position or are put into the closed position and thus always provide minimum or no outside air.
  - Improved comfort
    - Improved capacity turndown results in more stable space temperature and in a more uniform supply air temperature.
  - Improved acoustics
    - Reduced fan speed reduces noise and improved capacity turndown reduces the noise of compressor cycling.
  - Increased equipment life
    - Reduced fan speed reduces wear on fan motors and bearings.
    - Reduced economizer and compressor cycling also increases equipment life.
  - Better control of relative humidity
    - Both the fan control and the integrated economizer measure result in improved humidity control
  - Electrical system stability
    - Reduction in the large in-rush currents associated with frequent starting of large compressor drive motors.
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## NR10 – Single Zone VAV

# ACM Manual – System 1 and 2 – Package Single Zone

- Supply Fan Power: See Section 2.5.3.5 for design power. Fan power ratio at part load for variable speed = speed ratio  $\wedge$ 3 (e.g. 12.5% of design power at 50% speed).
- Supply Fan Control:
  - ~~Constant volume < 106 tons~~ proposed-calculated cooling capacity
  - ~~Variable Volume with 2-speed motor > 106 tons~~ proposed-calculated cooling capacity
- Partially integrated drybulb economizer. For DX systems with a cooling capacity of 65,000 Btu/hr or less. When economizer can meet load it provides entire load. When economizer can partially meet load, compressor cycles on and off, when compressor on economizer is closed and when compressor off economizer is fully open. (Note: Not currently modeled by DOE-2.1E or DOE-2.2)
- Supply Temp and Supply Fan Control: Supply air temperature setpoint shall be linearly reset from minimum at 50% cooling load and above to maximum at 0% cooling load. Fan volume shall be linearly reset from 100% air flow at 100% cooling load to minimum air flow at 50% cooling load and below. Minimum fan volume setpoint shall be 50%. (this is effectively an “airflow first” sequence”)

## NR10 – Single Zone VAV

# ACM Manual – System 5 – Four Pipe Fan Coil

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- Supply Fan Power: See Section 2.5.3.5 for design power. Fan power ratio at part load for variable speed = speed ratio  $^3$  (e.g. 12.5% of design power at 50% speed).
- Supply Fan Control:
  - Constant speed < ¼ bhp calculated fan power
  - Variable speed fan  $\geq$  ¼ bhp calculated fan power.
- Supply air temperature setpoint shall be linearly reset from minimum at 50% cooling load and above to maximum at 0% cooling load. Fan volume shall be linearly reset from 100% air flow at 100% cooling load to minimum air flow at 50% cooling load and below. Minimum fan volume setpoint shall be 50%. (this is effectively an “airflow first” sequence”)